Project Report: Delivery of Organic Materials to Planets

Letter from the Director
Baruch S. Blumberg

Dr. Blumberg describes the mission, organization, and character of the NAI, including a brief overview of its activities. He invites you to the NAI Annual Report for the science questions and answers that make astrobiology an exciting and rewarding scientific endeavor.

Welcome to the Annual Report of the NAI. In this introductory letter, I will discuss the organization, nature, activities, and scientific culture of the Institute. I hope this will be useful to members of NAI, to University officials and faculty at the institutions hosting NAI Teams, and to our colleagues at other NASA institutes and organizations. On a personal note, this is one of the few articles I have written on the administration of science. Nearly all of my professional writing has been on science itself, rather than its organization.

The Mission of Astrobiology

Astrobiology is concerned with life as a planetary phenomenon, that is, how biology interacts with objects in the Universe. It is the study of the origin, evolution, distribution, and future of life on Earth and in the Universe. Astrobiology addresses these fundamental questions: How did life originate? Are we alone in the universe? What is the future of humans in space? At a more basic level there are additional questions: What is life? How is it defined and characterized? When does life cease? How can its effects be detected and measured in fossil remains? How does biology affect its environment and leave measurable relics after the death or disappearance of the living material itself?

The Structure of NAI

The NAI is an *Institute* created by and included within the overall structure of NASA. This designation implies a measure of independence in its scientific program within the requirements of the NASA mission and the broad outlines provided by the *NASA Astrobiology Roadmap*. The *Roadmap* was prepared in 1998 following a July workshop, attended by several hundred members of the broad scientific community, convened at the NASA Ames Research Center (Ames). From its very inception, the science to be undertaken in NAI was in large part determined by scientists.

NAI provides a mechanism by which the creative research at universities, independent research institutions, NASA centers, and other organizations can be funded by and engaged in the NASA astrobiology endeavor. NASA operations are centered at NASA Headquarters in Washington, but many responsibilities are assigned to outlying NASA centers. Ames Research Center has been designated the site of excellence for astrobiology. The NAI leadership and management unit, designated NAI Central, is located at Ames.

The Director of Ames and the Administrator of NASA appoint the Director of NAI. The appointment

is made with the agreement of the Associate Administrators for three NASA enterprises: Space Science (which provides most of the NAI funding at 18−25 million dollars per year), Earth Science, and Biological and Physical Research. (The latter two enterprises each supply about 1 million dollars per year.) There are others involved in this appointment decision, including the Chief Scientist of NASA.

NAI program operations with eleven NAI Lead Teams formally began in July of 1998 with Scott Hubbard (now the Ames Director) appointed as Interim Director. I was appointed as the first NAI Director in May of 1999. The NAI Director reports to the Ames Director and through that person, to the Administrator of NASA. The Ames Director has the responsibility of maintaining good communications with appropriate officials at NASA Headquarters to keep them informed of NAI activities and plans.

The first Cooperative Agreement Notice (CAN) for NAI was released in October of 1997. A peer review committee made up of distinguished scientists from the scientific community selected eleven NAI Lead Teams (from more than 50 applicants) for five years of funding. A second CAN was released in 2000, and an additional four teams were selected from a field of more than 20 applicants. A third CAN will be released in late 2002. A different peer review Committee is selected for each of the CAN competitions to prevent the formation of a cadre of scientists who would have a long−term, and possibly oppressive, effect on research directions.

Each NAI Team is funded for five years at an average of about one million dollars per year. Teams may apply for an additional five years in competition with each other and also with Teams that have not previously been selected. Scientists choose the research they wish to do, within the broad confines of the *NASA Astrobiology Roadmap*. Peer review groups select the top candidates based on scientific merit, application to the NAI and NASA missions, and the quality of their education and public outreach programs. NAI funds a basic research and discovery program. I told the members of NAI that I don t expect them to do exactly what they said they would in their applications since, in discovery research, directions very often change. Discretionary funds are available to the Director to fund new research that might emerge during the course of ongoing research. Most of the discretionary fund allocations are also peer reviewed.

Since this is a cooperative program, the home institutions of the Lead Teams (i.e., the universities and research institutions, but not the NASA Centers) are expected to provide additional funding, usually in kind, i.e., paying the salaries of professors who are Team members, plus purchase of equipment. The home institutions provide, on average, about 40% of the funds received from NASA. We encourage the Teams to obtain funding from sources in addition to NASA.

The NAI has attracted an outstanding group of scientists. Principal Investigators of each Team decide the membership of their Teams, and their names are included in our NAI Directory with photographs of members. There are ~900 NAI members, with an estimated 150 who are senior scientists in the sense of being tenured faculty. There are 15 members of the National Academy of Sciences (NAS) in the NAI. Considering that NAS has fewer than 1500 members selected from all branches of science, the NAI has a remarkably high proportion of NAS members. It is encouraging that many of these scientists consider themselves, at least in part, active members of the NASA enterprise. The Institute organization appears to be an excellent mechanism to enlist the spirit and energy of American science to the mission of exploring the universe.

The Director has appointed a Science Council of advisors, including distinguished scientists and several Nobel Laureates.

The Nature of NAI

NAI is a basic research institution. Hence, the outcome of the research is not apparent until it is done. The direction of research is the responsibility of the individual investigators, and the role of NAI Central is to facilitate their programs. Overall, its goal is to serve the mission of NASA, and many of the NAI basic research projects are directed to one or more of the present, planned, or contemplated space and airborne missions. It was recognized that astrobiology cannot be the province of a single discipline and that multiple disciplines need to be brought to bear on the problem. This was resolved by the simple expedient of requiring all NAI Teams applying for the CAN to include representatives from two or more disciplines. The general trend in science is to become more and more specialized in a narrow discipline. NAI is organized in the opposite manner. Any single scientist cannot be expected to be expert in the multiple disciplines, but the Teams taken together encompass all of them, and the expectation is that they will support each other.

Astrobiology is an interesting mixture of scientific processes. One approach emerges from historical sciences that make up a large part of the astrobiology enterprise: astronomy, geology, paleontology, field biology, and ecology. Events have happened, and it is the task of the scientists to tell the explanatory story. It is *inductive* science in that the data are collected first, then the hypotheses are formulated. It is based on fieldwork and observation. A large percentage of our scientists spend a significant part of their time in the field, often in remote and barren places with extreme environments.

A second astrobiology approach emerges from the ethos of contemporary medical/biological research. It is *deductive* in the sense that it is hypothesis−driven. The hypothesis is stated first, then data are collected to test it. This approach is primarily (although not exclusively) experimental and reductionist. There is a strong emphasis on experimentation in which the scientist creates a universe that is, or is assumed to be, a *simulacrum* of the real world beyond the laboratory bench. In biological research, it is difficult to fund inductive research; it is often denigrated as a "fishing expedition." It is hard to understand this attitude or the metaphor. If the scientist wants to find something new, it is necessary to search in places not previously explored; if you want to catch fish, then a fishing expedition is the appropriate activity.

Astrobiology is a fascinating amalgam of these aspects of scientific processes, and it values both research approaches. Space science and astrobiology are appealing because of their newness. We can now look at and measure phenomena, which were not seen or measured before, because the means to do so were not available. We now have space ships, rockets, and satellites. They allow searches into the universe not available as little as a decade ago. It is akin to van Leewenhoeck's microscope or the telescopes of Newton and Galileo. Each space venture discloses objects and events that had not been seen before. Astrobiology is a great producer of new ideas from which new hypotheses and models can be formulated.

International Associations and Affiliations

Space exploration cannot be done by the U.S. alone. If humans explore Mars sometime in the future, it is unlikely that they will all be Americans. The organic documents that govern the NAI excluded the funding of international teams. Therefore, our international relations are scientific and collaborative.

When the NAI began formal program operations in 1998, the newly formed Spanish astrobiology group (*Centro de Astrobiologia*) requested an association with the NAI. This was instituted at a

government−to−government level. In the past three years, several other national astrobiology organizations have become affiliated with NAI. This usually occurred through associations between NAI members (including members of NAI Central) and scientists from other countries. They, in most cases, approached us with a request to form an association or affiliation. In several cases, the national organizations have been formed specifically to allow the NAI affiliations.

We do not judge the international partners since, presumably, their own scientific community has evaluated them. We review the requests of international groups (often performed by members of the Director s Science Council) in order to determine how their program interacts with our own and other international groups. *Associates* are based on government−to−government agreements. *Affiliates* are based on scientist−to−scientist arrangements. The nature of the partnership can be changed on the request of the international partner. NAI Central works in conjunction with the Associate Administrator for External Relations at NASA Headquarters and the appropriate offices at the U.S. State Department. A recent development has been the interaction of the international organizations with each other in the form of collaborative research projects, visits of students and postdoctoral scientists, and joint field trips. The role of NAI in these activities is to facilitate the interactions without interfering. The current international Associate is *Centro de Astrobiologia* (Spain). Current international Affiliates are: *United Kingdom Astrobiology Forum and Network; Australian Centre for Astrobiology; Groupement de Recherche en Exobiologie* (France); and *European Exo/Astrobiology Network Association (EANA)*. Discussions are in progress with other countries for possible additional international partners.

The international program of NAI is an interdependent program of scientists helping to ensure effective collaboration and scientific exchange, while recognizing the international character of science and the great human effort that is required for space science in general and astrobiology in particular.

Education and Public Outreach

Basic scientific research is the major mission of NAI. Education and public outreach is an additional important task. In democracies, science is conducted with permission of the public (who pay for most basic research) and their elected representatives. It is the responsibility of scientists to tell the public what they are doing and hope to do. This allows the public and their political representatives to make intelligent evaluations of the national science program. NAI invests a significant portion of its budget in this program. Krisstina Wilmoth, NAI Education and Public Outreach Manager, describes this program in detail elsewhere in this report.

Astrobiology has a peculiar generational character. Because of the long distances traveled by space missions and the time needed to complete them, a scientist may not be able to plan a program and mission, define the observations to be made and hypotheses to be tested, and obtain all the results within a single scientific lifetime. For example, Europa is one of the main targets for astrobiology research, and plans for its exploration are underway. It takes five years to reach Europa (at current propulsion speeds) and many more years for orbiting, landing, and return missions. Studies started by a contemporary scientist will have to be completed by his or her (or someone else s) children, grandchildren, and great−grandchildren. It is similar to the construction of cathedrals over the course of many generations and hundreds of years. Astrobiology is in this sense altruistic, in that the person who starts the job may not finish it. Of course, there are scientific results during the course of a grander mission, and there are many opportunities to publish scientific papers.

NASA and NAI have an extensive program for teacher training, providing materials for K−12 and

higher levels. There are more than 100 undergraduate courses in astrobiology and similar subjects. Nearly all of these have started within the past two years. In many institutions, the course can satisfy the science requirement for non−scientists. There are new undergraduate astrobiology texts in the field, and others will soon become available.

Ph.D. programs for astrobiology are in place or planned in several of the university−based NAI Teams. The degree is usually awarded in an established discipline (i.e., astronomy, geology, biology, genetics, etc.) with additional training in astrobiology; it is recognized by a certificate awarded along with the Ph.D. Many pre−doctoral students are funded directly or indirectly through the NAI grants to the Teams.

A testimony to the growth of this field is the recent publication of two new professional journals: *Astrobiology* (published in the United States) and *The International Journal of Astrobiology* (published in the United Kingdom). Members of the NAI Teams and NAI Central serve on the Editorial or Advisory Boards of these journals.

The "Virtual Institute"

NAI is a distributed organization with 15 national sites and several international Associates and Affiliates. Developing methods for conducting a "virtual institute" is a major mission of NAI. Virtual institutes have the advantage of combining the efforts of many scientists from different disciplines and with different interests to work on projects in which they are mutually interested. It can be argued that it would be better to have all of them in a single location. Counter arguments to this are the difficulty of recruiting and moving so many scientists to the same location, plus the cost of building and maintaining a large single venue. It is better to spend the money on research and utilize the buildings and equipment supplied by the home institutions. A variety of devices and processes have been introduced at NAI to facilitate development of collegiality and collaboration and to mitigate the disadvantages of separation. This requires appropriate communication and knowledge management hardware and software. But, it also requires an understanding of the sociology and even psychology of scientists and the ways in which they interact. The NAI Collaborative Research Manager, Lisa Faithorn, discusses this program elsewhere in this report.

We supply videoconferencing capability for each of the NAI Lead Team institutions. The quality of the equipment and capabilities has been greatly improved in the past two years. Part−time information technology (IT) managers have also been appointed at each of the Teams. A major effort has been directed to identify other electronic means to improve interaction. An extended needs assessment was conducted this year, using a survey managed by the NAI Collaborative Research Manager. One outcome will be the selection of personal computer−based conferencing, communication, and knowledge management systems to facilitate the inclusion of NAI members not at the Lead Team institutions for conferences and other meetings.

Electronic devices are only a part of the program. Several methods have been established to increase collaboration and interaction. Focus Groups (discussed elsewhere) bring together scientists of like interests, both from within and outside of NAI. Established and functioning NAI Focus Groups include these: Mars Focus Group, Ecogenomics Focus Group, Mission to Early Earth Focus Group, Evogenomics Focus Group, Europa Focus Group, and Astromaterials Focus Group. Recently formed NAI Focus Groups include these: Titan Focus Group, Virus Focus Group, and Biological Consequences of Impacts Focus Group. These various Focus Groups have proven to be one of the most effective mechanisms for bringing together scientific interests of NAI members, as well as including scientists not in the NAI. Videoconferencing is particularly useful for the meetings of these groups.

We fund about 12 NAI Post Doctoral Fellows per year. In addition to their stipends, the Fellows are provided with funds to spend short or long periods at NAI Teams other than their home Team. This arrangement expands their experience and helps to convey scientific knowledge from one NAI Team to another. Funds are also available for members of different NAI Teams to take part in each othe s field trips.

NAI−wide Seminars using our videoconferencing facilities are held frequently. These include the Director s Seminars for presentations by the senior scientists and other Team Members, plus a Student Video Seminar Series, organized by the student astrobiology institutes or groups that have formed at several of the Teams. Other mechanisms to foster interactive connections are being developed.

Conclusions

Four years of scientific work have been completed by NAI since it began operations in 1998. There is a long path to tread before it gains the maturity of an established institution, but it is fair to say, that it has already had an impact on the exciting field of astrobiology.

NAI has provided significant funding to the creative genius of U.S. academic and government science at a crucial time when the astrobiology field is expanding. It has supported, in whole or in part, many of the scientific leaders in the field and encouraged those who are not members of the NAI. It is a haven for basic and exploratory science where the scientists can request funds to do research of their own choosing, within the broad confines of the *NASA Astrobiology Roadmap* with the expectation that they can shift their directions when new findings warrant change. Its role as a virtual institute has required it to develop methods to facilitate collaboration between scientists at locations distant from each other, including those in other countries. Public outreach and the education of young and more mature scientists is a major part of its activities, recognizing that astrobiology is a long term human activity.

We hope that this and future NAI Annual Reports will reveal the questions and answers that have made astrobiology an exciting and rewarding scientific endeavor. Basic science findings generated by astrobiology research can answer questions of vital interest to both science and the public. They will, in time, also contribute to important applications in industry and applied science.